Performance and Calibration of a $2m^2$ SM2 Micromegas Detector for the ATLAS Muon Spectrometer Upgrade

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Abstract

The steadily increasing luminosity of LHC requires an upgrade to high rate capability and high resolution capable detector technologies for the innermost station of the muon spectrometer of the ATLAS experiment. For precision tracking 4 types of 2 and 3 m^2 large Micromegas quadruplets will provide 8 consecutive active layers, each with 100 μm spatial resolution per individual plane. Data taken at the 120 GeV SPS muon and pion beam in August 2017 on one 2 m^2 quadruplet prototype (SM2 built by the German consortium), show spatial resolutions of 80 μm for perpendicular particle incident. The full active area of the SM2 prototype quadruplet has been calibrated in the Munich Cosmic Ray Facility (CRF).

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1. Introduction

Large size resistive Micromegas detectors (MM) will be employed for the Muon Spectrometer upgrade of the ATLAS experiment at CERN. The current innermost stations of the muon endcap system, the Small Wheel, will be upgraded in order to retain the good precision tracking and trigger capabilities in the high background environment expected with the upcoming luminosity increase of the LHC. Two technologies will be used in the New Small Wheel (NSW), the small-strip Thin Gap Chambers (sTGC) and the Micromegas, both arranged in multilayers of two quadruplets. All quadruplets have trapezoidal shapes with surface areas between 2 and 3 m^2 . The MM system will provide both trigger and tracking capabilities. Each MM plane has to achieve a spatial resolution better than 100 μm independent of the track incidence angle and operate in an inhomogeneous magnetic field ($B < 0.3$ T), with a rate capability up to 15 kHz/ cm^2 . The performance studies and calibration for the SM2 quadruplet constructed by the German consortium is presented. Results that are presented in this paper are from the first constructed full-size chamber (Module0) based on read-out panels built with pre-series PCBs. The performance of the SM2 quadruplet was studied at the LMU Cosmic Ray Facility and at the test beam at CERN. The CRF is equipped with two 4x2.2 m^2 Monitored Drift Tube (ATLAS MDT) chambers for precision muon reference tracking, two scintillator trigger hodoscopes, providing additional trigger segmentation along the read-out strips and along the MDT wires. Due to the active area of about 9 m^2 and an angular acceptance between -30° and $+30^\circ$ track

analysis provides information of strip positions within the read-out plane as well as information on the perpendicular dimension and the distance between active planes. An iron absorber is used in order to cut the low energy muons ($E_\mu > 600 MeV$). The Micromegas under test is placed between the MDT reference chambers. In the test beam at H8 area at SPS the SM2 detector was investigated with muons and pions of energy 120 GeV. A two dimensional reference tracking system was implemented using 3 GEMs and 2 TMM chambers.

2. Efficiency of the detector

The efficiency of the SM2 quadruplet was studied at the CRF operating it with an amplification high voltage of 600 V. The tracking efficiency and the most probable value of the pulse height distribution are shown in Fig.1. The efficiency is defined as the fraction of good tracks with at least 1 hit within 5 mm from the reference tracks. The measured efficiency of the first detectors was at $\epsilon > 90\%$ in most of the active area. The detector has a central region fully efficient and two other regions with sizeably lower efficiency and signal. The decreasing efficiency at the very borders expected due to rectangular segmentation of the scintillators that were used during the measurements while the SM2 detectors have trapezoidal geometry and the muons could give trigger but were not able to transverse the active area of the quadruplet. The unusual white area that is observed in the central region of the detector is due to trigger problems and surely induced by the low statistics. The differences between nearby areas of the detector is due to limited readout PCB quality of preseries PCBs.

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Figure 1: Mapping of the full active area for pulse height (left) and efficiency (right) at 600V for the eta layer. Results are from CRF

Pulse height and efficiency have also been studied as a function of the high voltage in the amplification region in a fixed detector position. The cluster charge increases exponentially while the high voltage is rising, as expected (see Fig.2). The

Figure 2: Pulse height (left) and efficiency as a function of high voltage applied to the amplification region (right) for the four Micromegas gaps (eta in/out, stereo in/out) of the quadruplet. Results are from the CRF.

efficiency of a large area of the detector during the increase of the amplification voltage is same for all 4 layers. We assume the differences that appear at high voltages are due to different readout PCB quality. Measurements of the efficiency of the full layer are similar and give a plateau for voltages above 590 V.

3. Resolution

For the performance studies of the SM2 chamber, the spatial resolution was measured at the test beam. The method used is the charge weighted position reconstruction method for the perpendicular tracks. The results of this method for the eta panel on both sides present an excellent resolution. The measured resolution for perpendicular tracks is about $80\mu\text{m}$ with no dependence on the amplification high voltage as shown in Fig.3 (left). On the other hand the spatial resolution based on the charge weighted centroid turns out to be strongly dependent on the incidence angle, as shown in Fig.3 (right). The encouraging outcome is that the resolution is independent of the amplification high voltage. Studies of small Micromegas display as expected a similar resolution dependency with the incident angle. Both sides of the produced eta panel, show similar dependence of the resolution.

4. Precision calibration

Using perpendicular muon tracks and exploiting the very good spatial accuracy of the MDT chamber, it is possible to

Figure 3: Spatial resolution as a function of high voltage applied (left) and of the incident angle (right) compared to results from small-size chamber prototypes. Results are obtained during the H8 CERN Test-Beam.

measure the strip position at the LMU CRF with high accuracy ($\sim 20\mu\text{m}$) in such a way to spot possible misalignment problems of the detector. Fig.4 (left) shows the residual mean as a function of the precision coordinate given by the MDT chamber track. Significant shifts between extrapolated and reconstructed track position are clearly visible. A shift of about $450\mu\text{m}$ observed between strip positions should be due to misalignment of the electronic adapter board. The pitch deviation from the nominal pitch (blue line) is measured in the order of 100 nm and is probably due to thermal effects.

Figure 4: Precision calibration of PCBs before (left) and after correction (right). Results are from CRF.

5. Conclusions

The performance and the calibration of a SM2 Micromegas quadruplet was presented. Quality control of the SM2 quadruplets in the Cosmic Ray Measurement Facility (CRF) using reference muon tracks includes measurements of the efficiency, the pulse height and calibration of the strip positions. The SM2 detector shows a good uniformity of the efficiency over the active area and of the pulse height within 20%. The spatial resolution around $80\mu\text{m}$ for the perpendicular tracks is excellent.

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